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(54) **SUBSTRATE CARRIER AND FACILITY INTERFACE AND APPARATUS INCLUDING SAME**

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(51) **Int. Cl.**
B65B 1/04 (2006.01)

(52) **U.S. Cl.** **141/63**; 206/213.1; 206/711

(58) **Field of Classification Search** 141/63, 141/98; 118/715; 206/711
See application file for complete search history.

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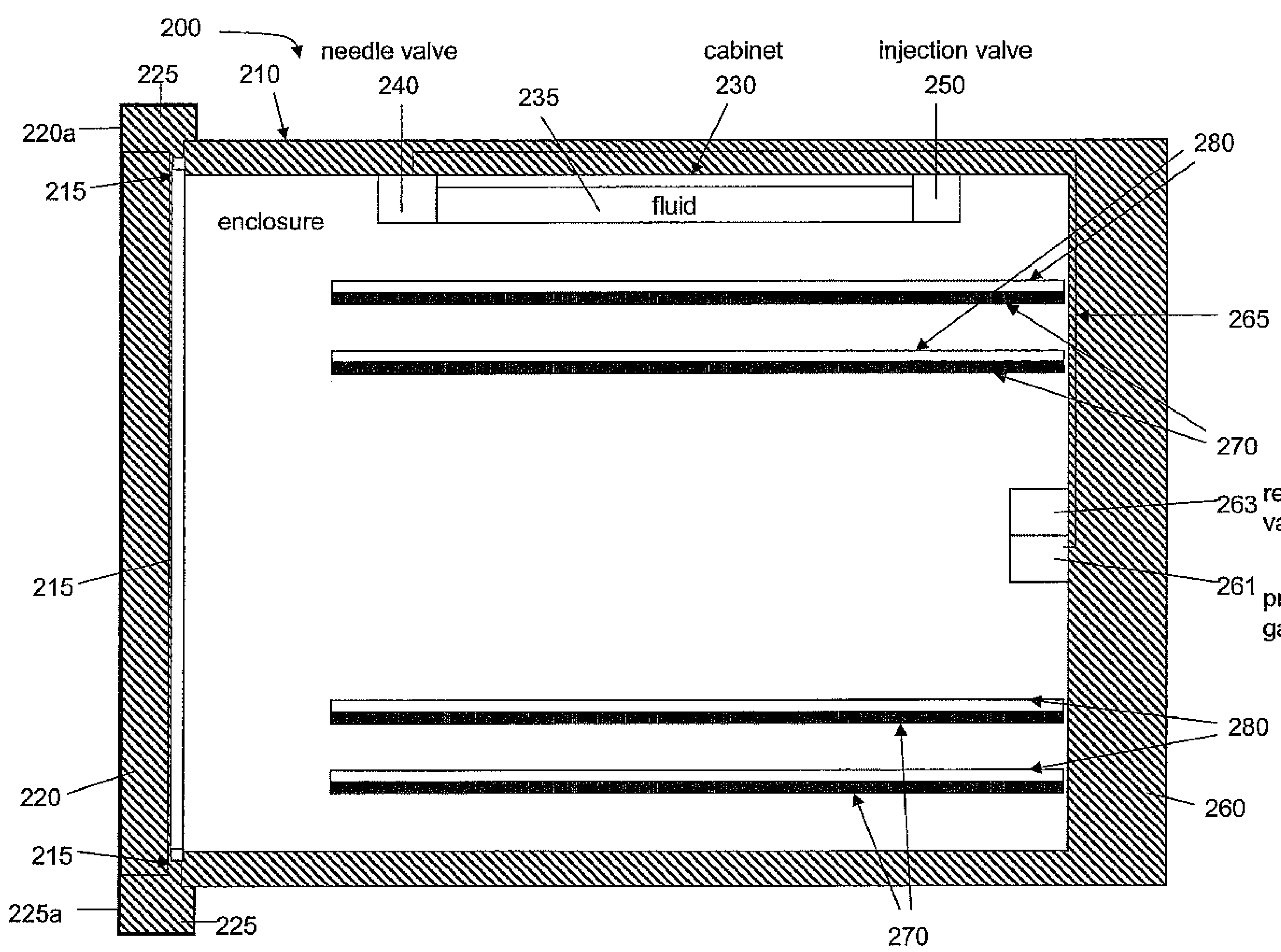
(57) **ABSTRACT**

A carrier comprises an enclosure, a cabinet and at least one substrate holder. The enclosure comprises a door. The cabinet is coupled to the carrier. The cabinet comprises at least one valve and contains at least one reduction fluid. The substrate holder is disposed within the enclosure to support at least one substrate.

15 Claims, 9 Drawing Sheets



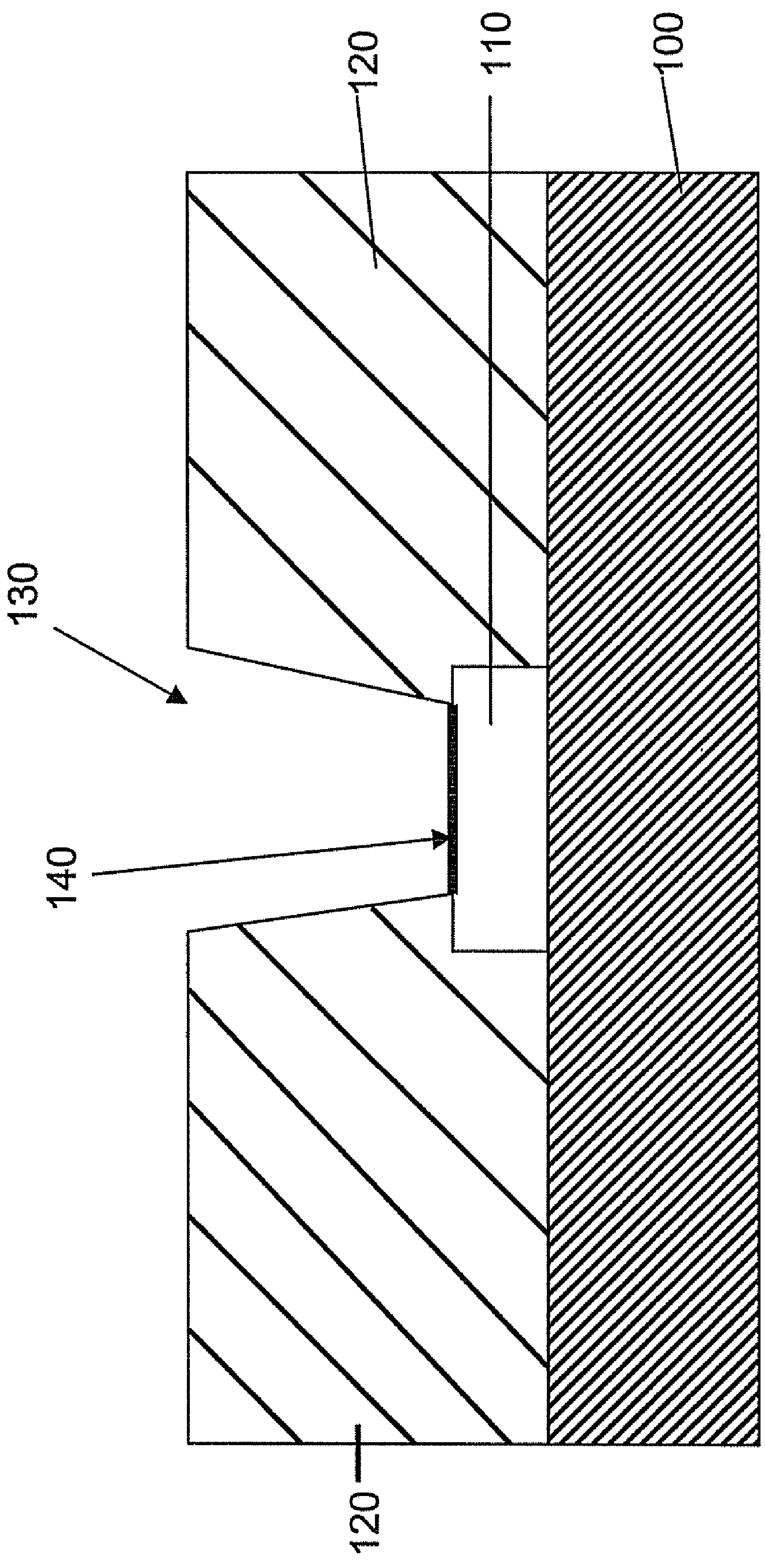
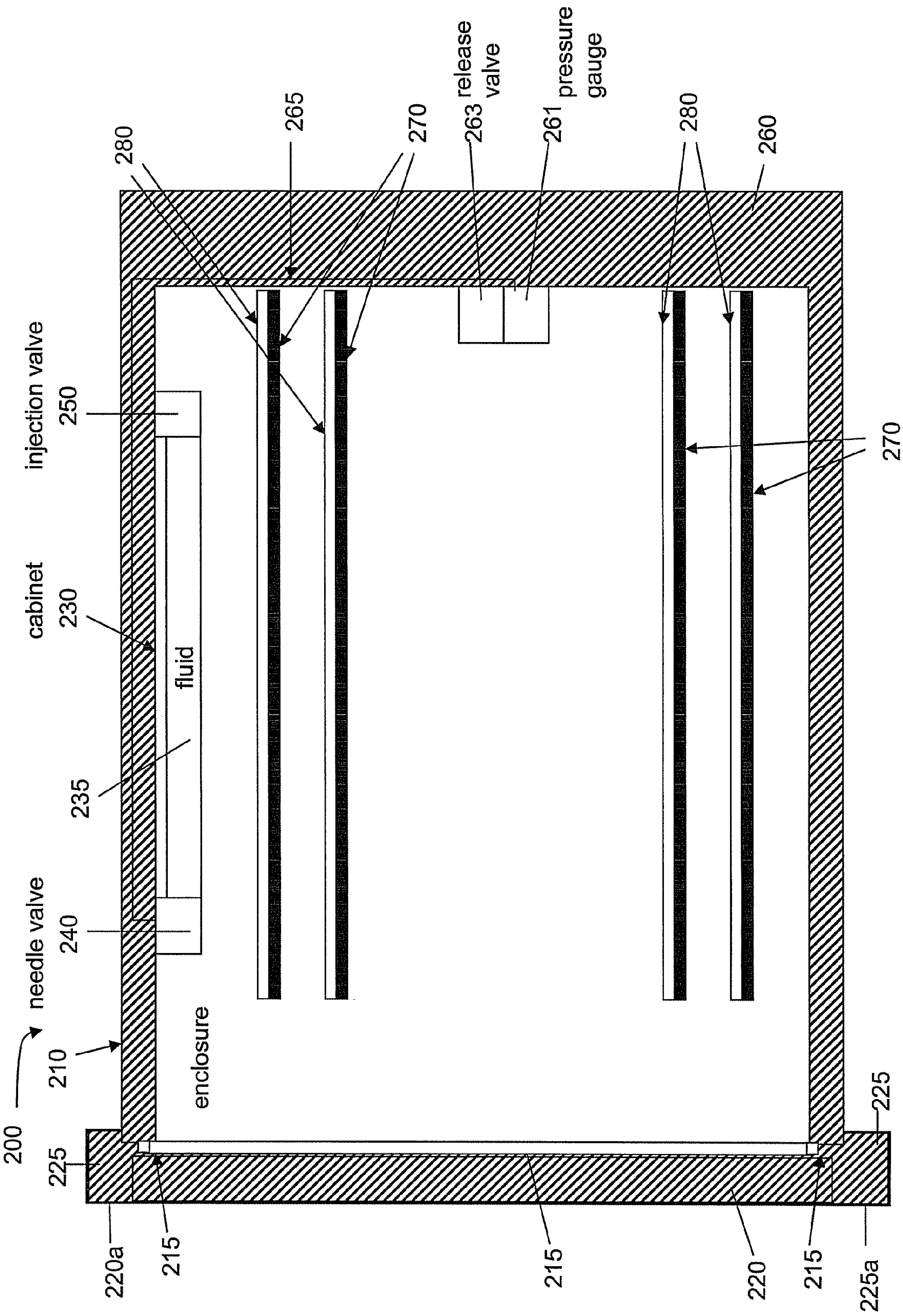


FIG. 1
(PRIOR ART)



200
210
enclosure
needle valve
240
cabinet
230
fluid
235
injection valve
250
265
280
270
263 release valve
261 pressure gauge
260
225
220a
215
220
225a

FIG. 2A

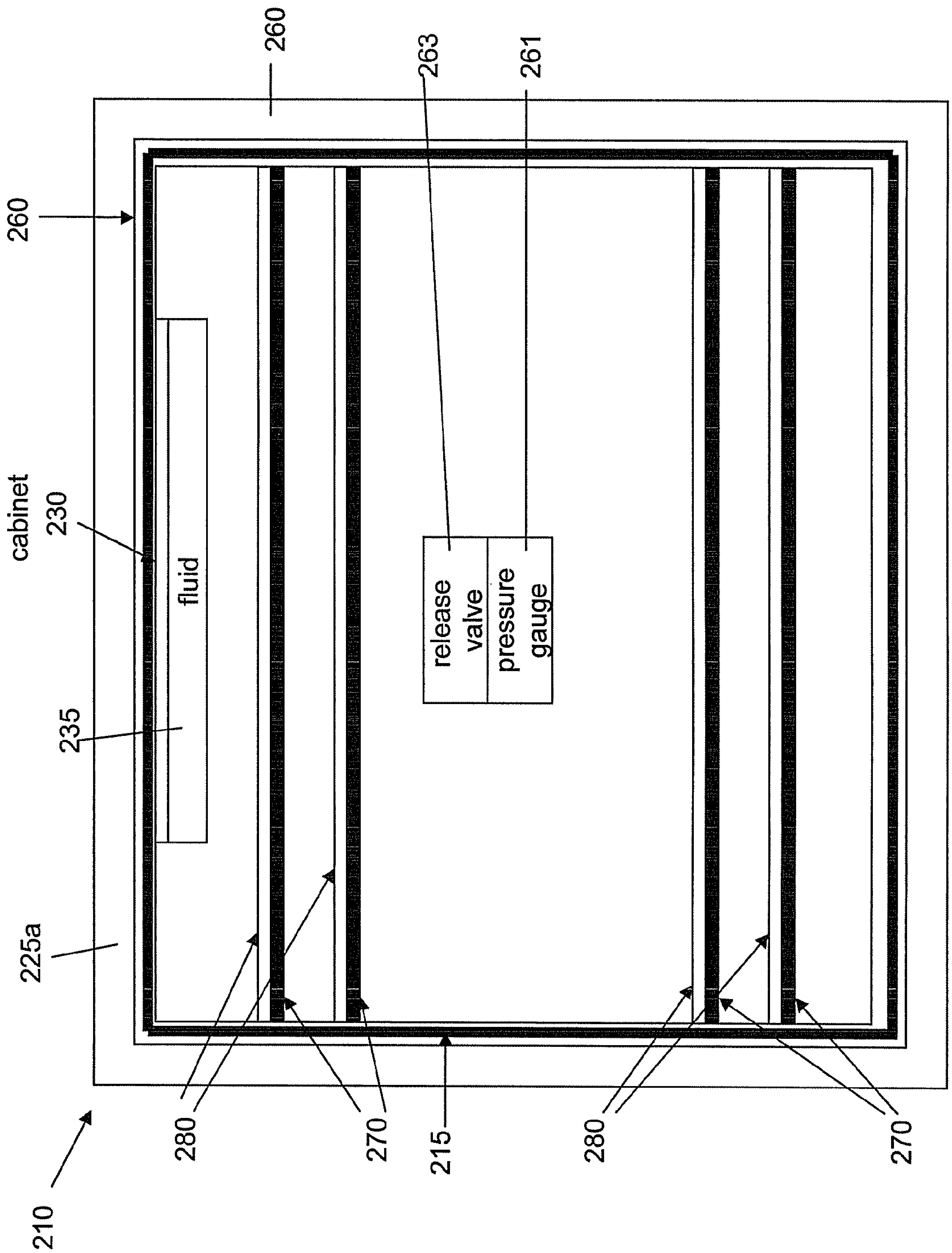

260
263
261
260
cabinet
230
fluid
235
225a
release valve
pressure gauge
280
270
215
280
270
210

FIG. 2B

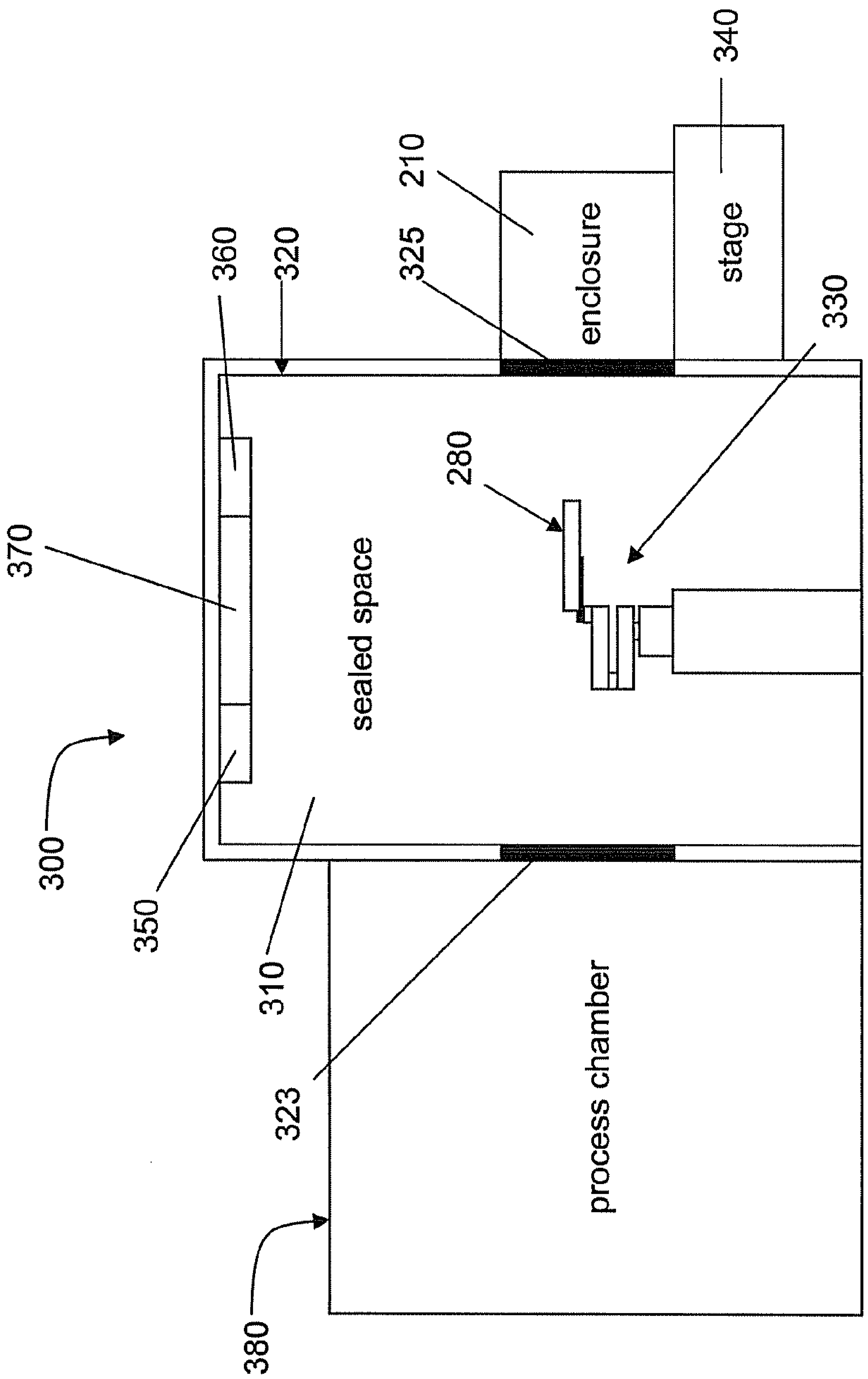

340
210
stage
enclosure
325
320
360
330
280
370
sealed space
300
350
310
323
process chamber
380

FIG. 3A

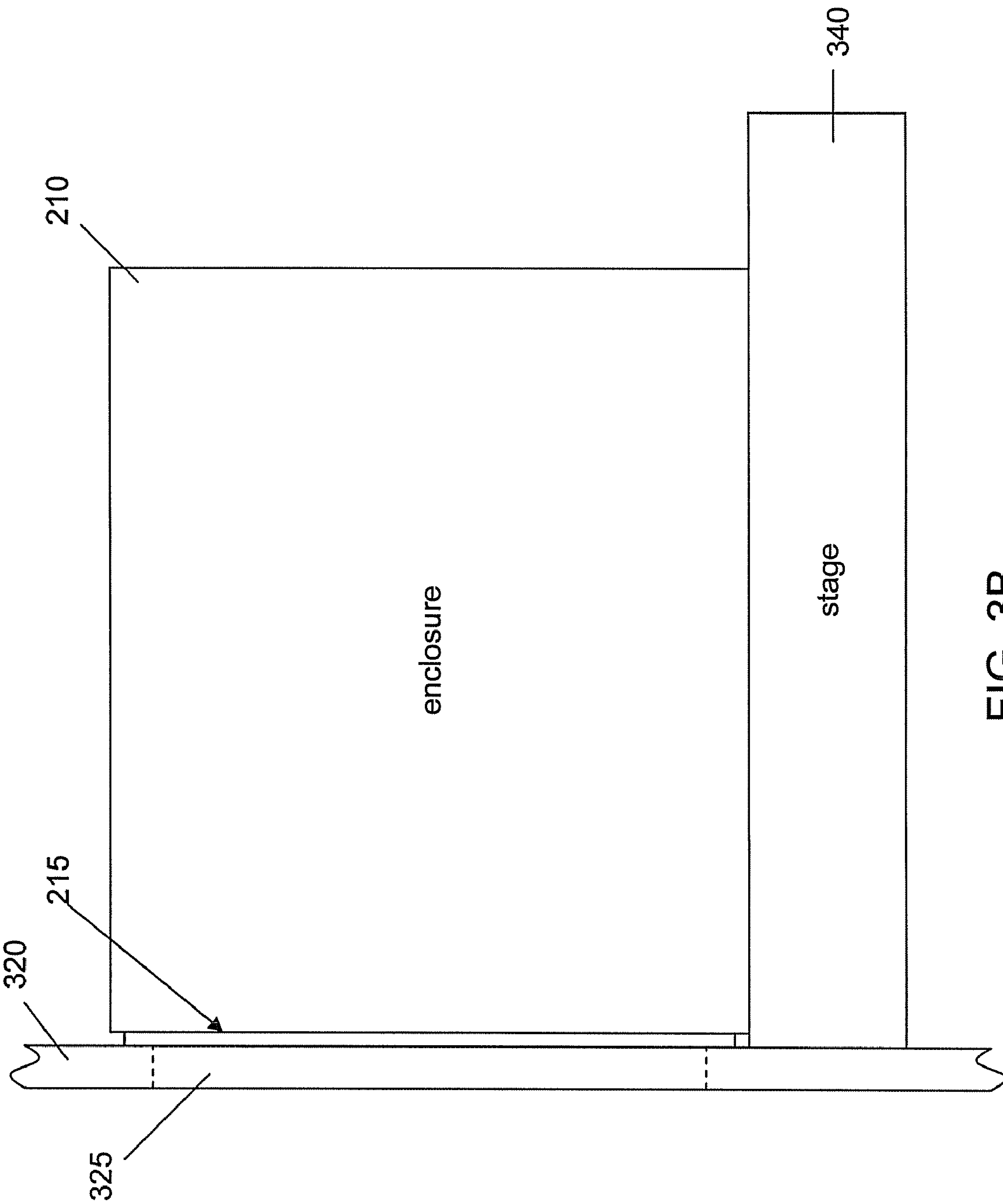


FIG. 3B

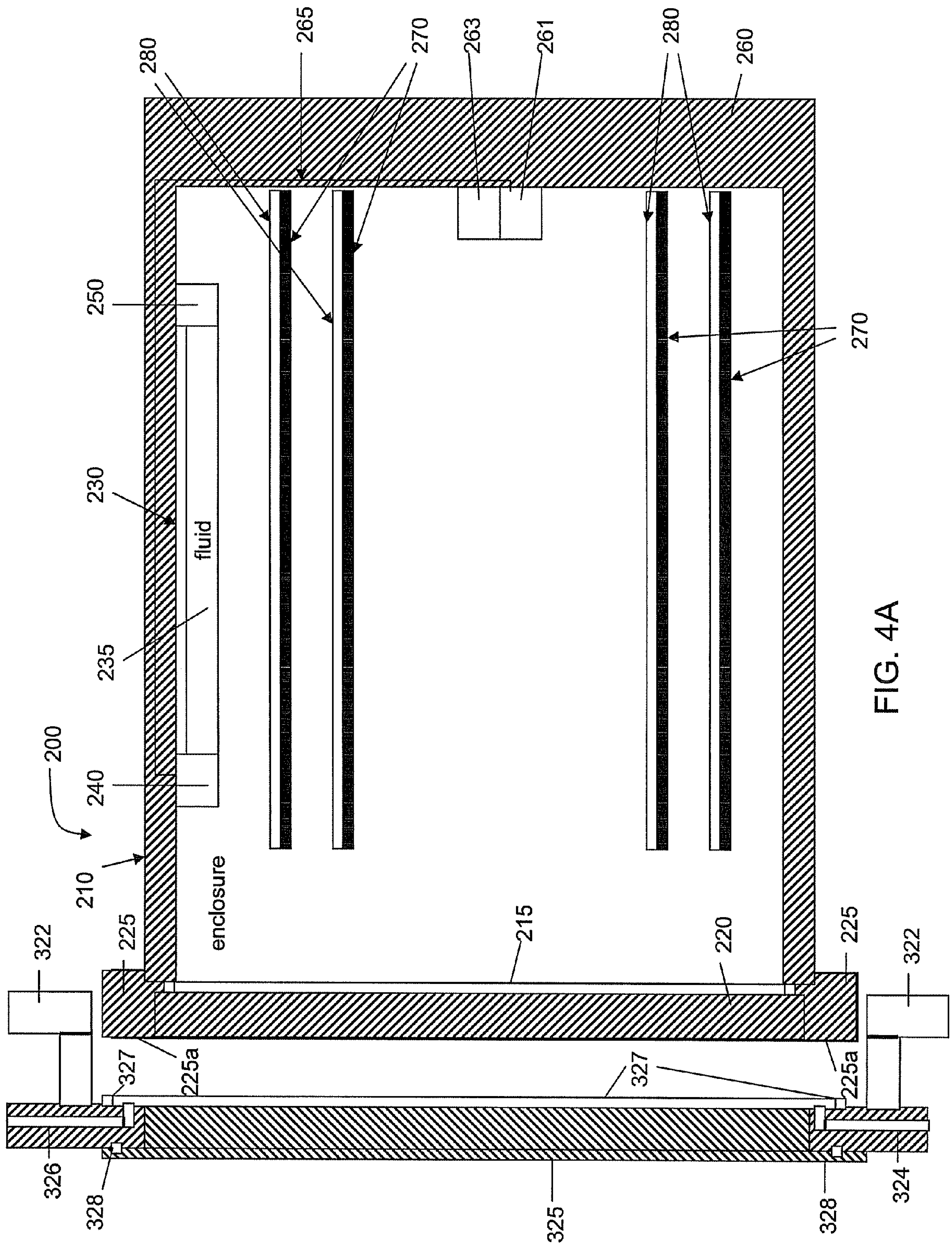

200
210
215
220
225
225a
230
235
240
250
260
261
263
265
270
280
322
324
325
326
327
328
fluid
enclosure

FIG. 4A

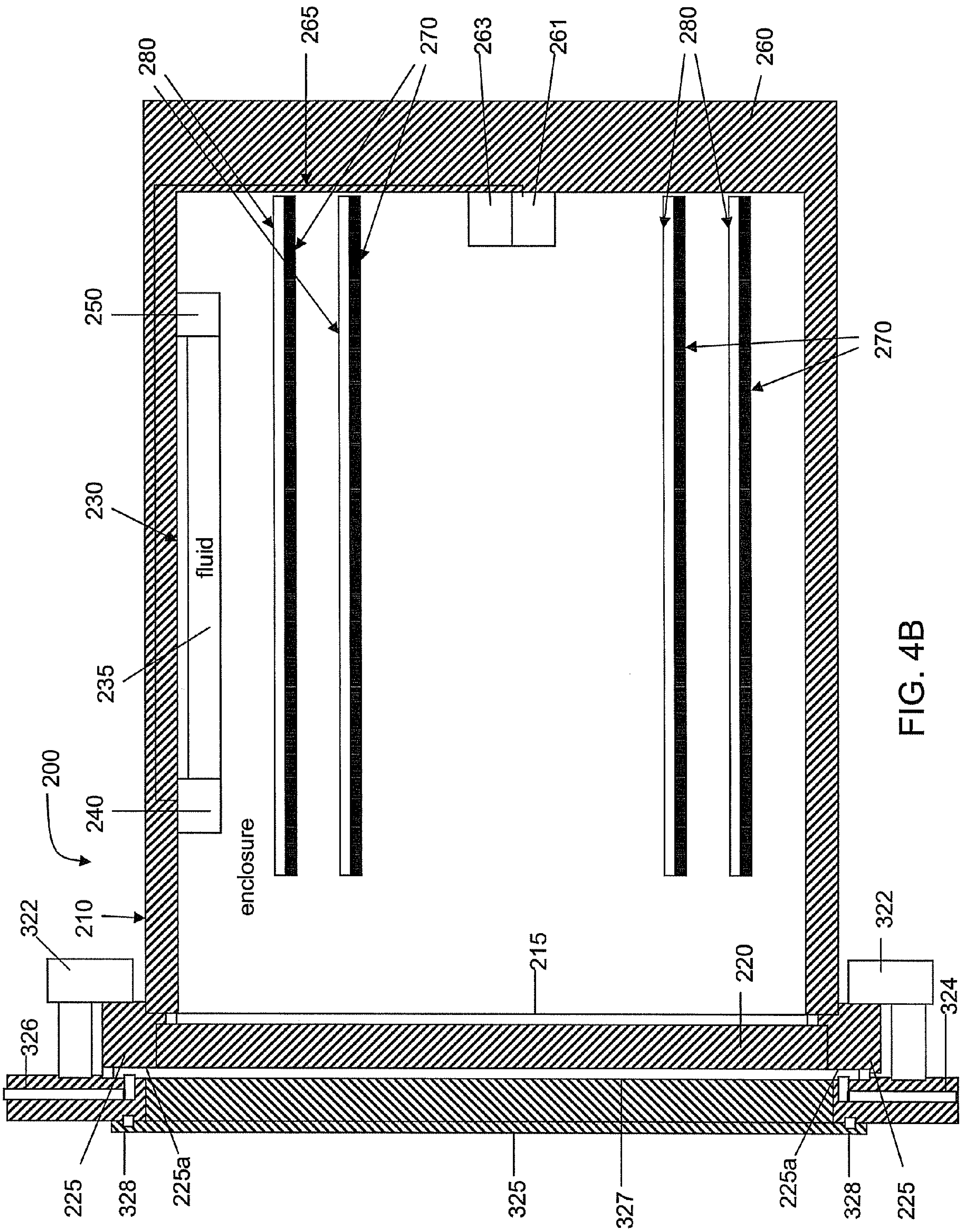

265
270
263
261
280
260
280
250
270
230
fluid
235
200
240
enclosure
322
210
215
220
322
326
324
225
328
225a
325
327
225a
328
225

FIG. 4B

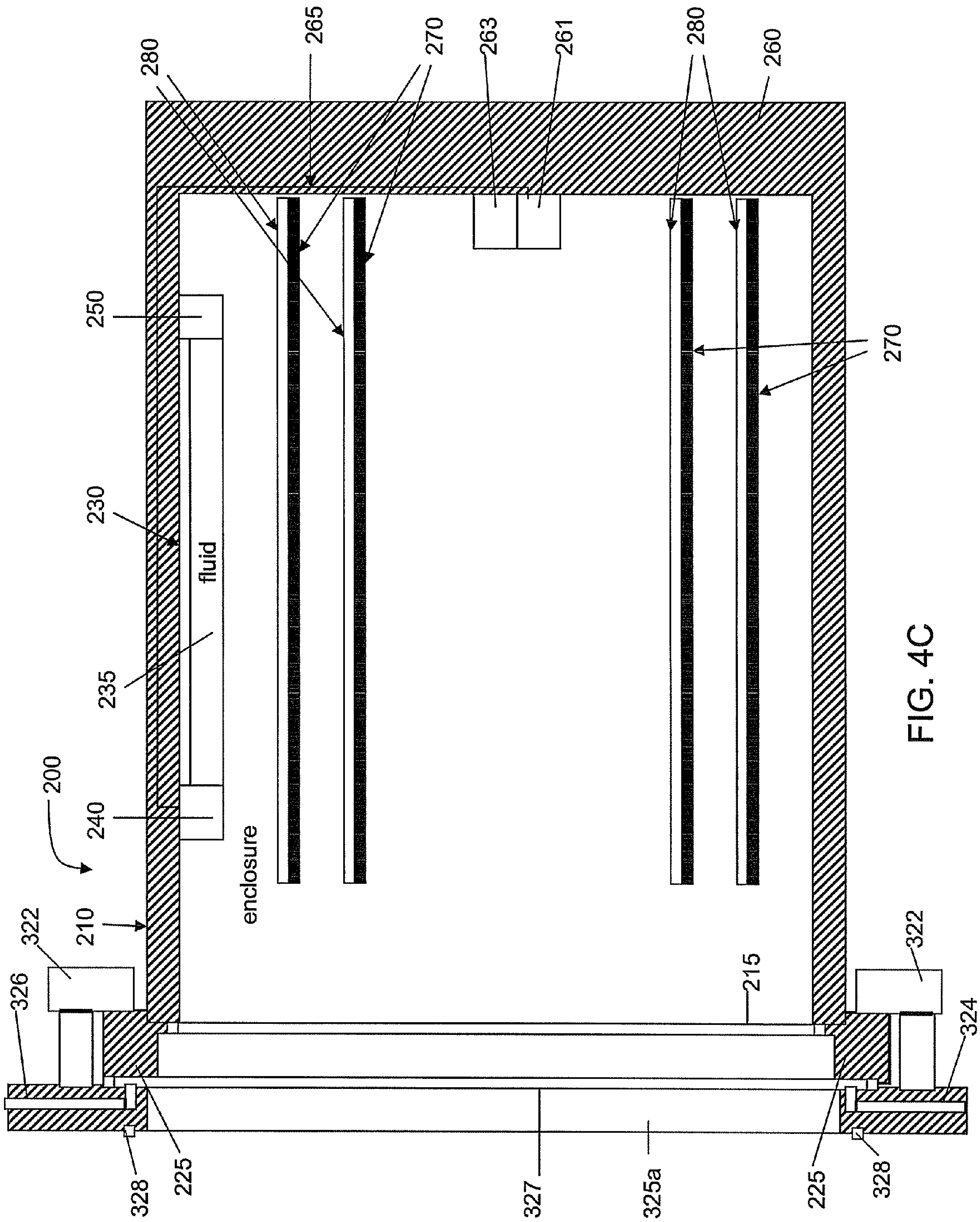

280
265
270
263
261
280
260
250
270
230
fluid
235
200
240
enclosure
210
322
326
215
322
324
328
225
327
325a
225
328

FIG. 4C

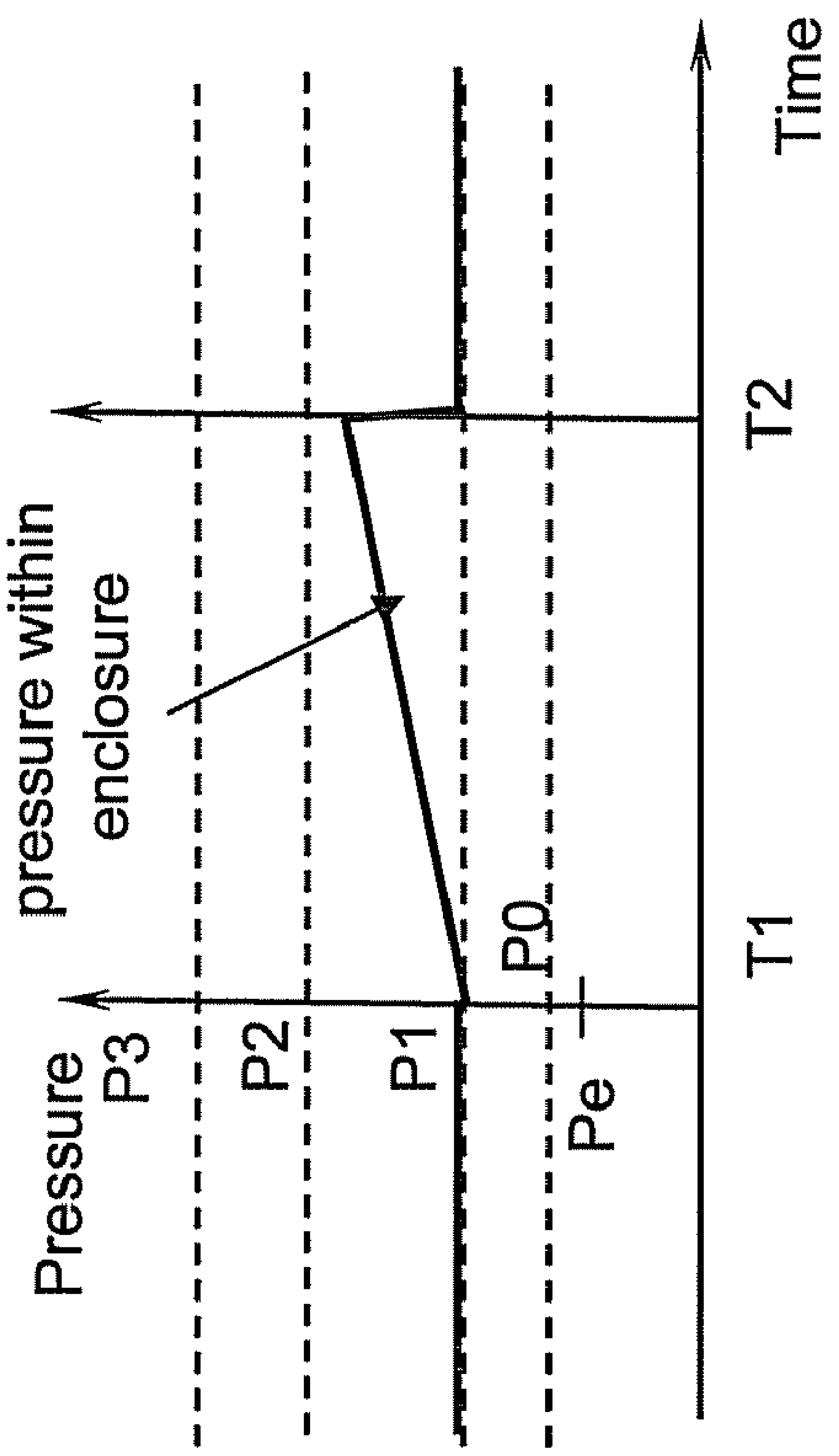

Pressure
P3
P2
P1
Pe
P0
pressure within enclosure
T1
T2
Time

FIG. 5A

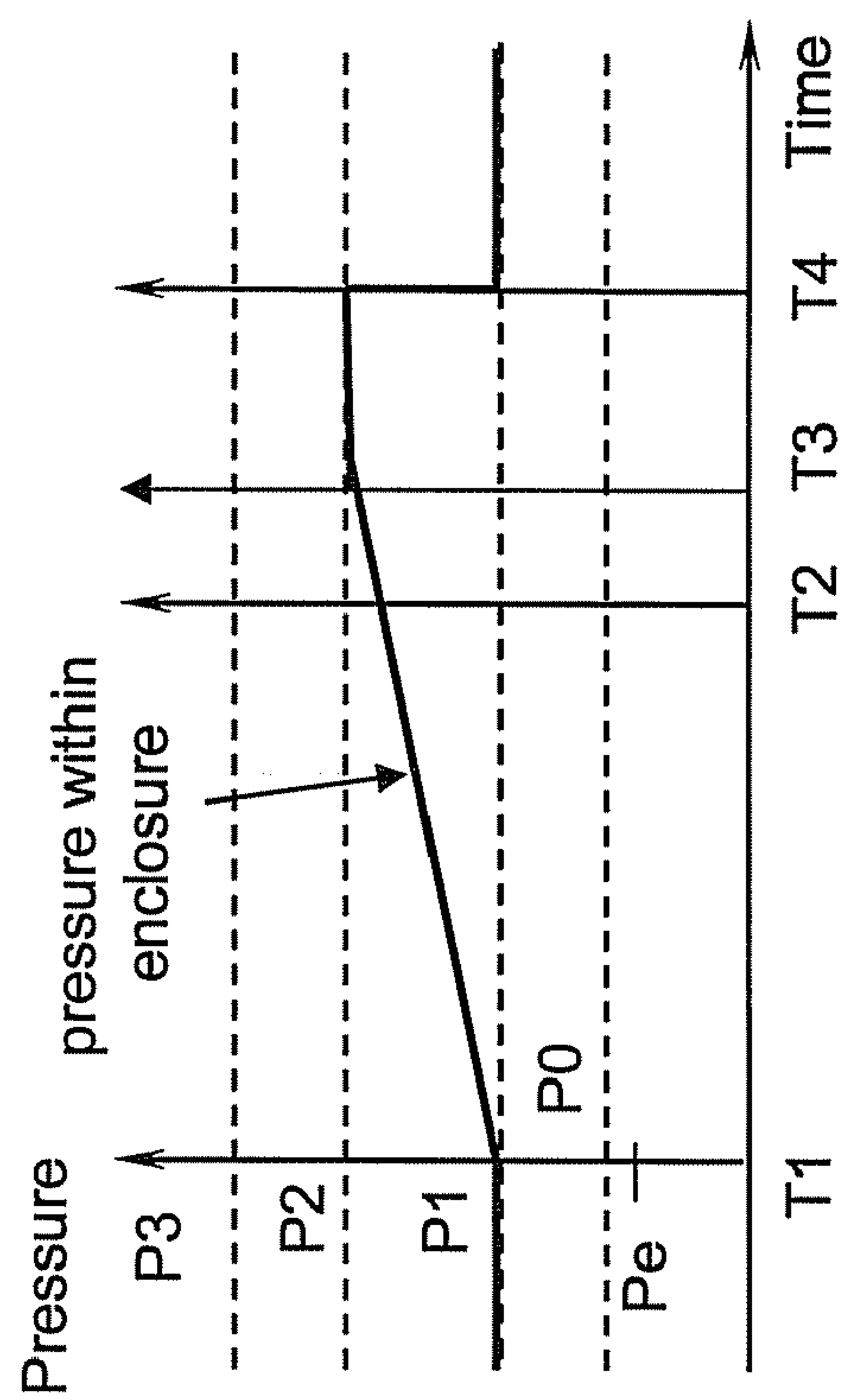

Pressure
P3
P2
P1
Pe
P0
pressure within enclosure
T1
T2
T3
T4
Time

FIG. 5B

SUBSTRATE CARRIER AND FACILITY INTERFACE AND APPARATUS INCLUDING SAME

This application claims priority of the filing date of U.S. Provisional Patent Application No. 60/747,445 filed May 17, 2006, which provisional patent application is hereby formally incorporated by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to carriers and facility interfaces, and more particularly to semiconductor wafer carriers and facility interfaces.

2. Description of the Related Art

With advances in electronic products, semiconductor technology has been applied widely in manufacturing memories, central processing units (CPUs), liquid crystal displays (LCDs), light emitting diodes (LEDs), laser diodes and other devices or chip sets. In order to achieve high-integration and high-speed requirements, dimensions of semiconductor integrated circuits have been reduced and various materials, such as copper and ultra low-k dielectrics, have been proposed along with techniques for overcoming manufacturing obstacles associated with these materials and requirements.

FIG. **1** is a schematic drawing showing a traditional via hole structure. A copper layer **110** is formed over a substrate **100**. An ultra low-k dielectric layer **120** is formed over the copper layer **110**. A via hole **130** is formed within the ultra low-k dielectric layer **120** to expose the top surface of the copper layer **110**. If the copper layer **110** is exposed to air, the top surface of the copper layer **110** reacts with oxygen in air, forming a copper oxide layer **140** due to oxidation. The copper oxide layer **140** can adversely affect the electrical connection between the top surface of the copper layer **110** and a conductive via plug filled into the via hole **130**. In addition, the ultra low-k dielectric layer **120** absorbs moisture when exposed to air. Accordingly, great care should be taken to avoid exposure to air during critical process steps, such as via opening, formation of copper seed layers, copper chemical mechanical polish (CMP) and formation of the ultra low-k dielectric material.

Traditionally, after a critical process step, the substrate **100** is removed from the process chamber that performs the critical process step and temporarily stored in a cassette or front opening unified pod (FOUP) until subsequent processing. When the door of the cassette or FOUP is removed to allow placement of the substrate **100** in the cassette or FOUP, air from the surrounding environment including oxygen flows into the cassette or FOUP. After the door is closed, the air is sealed within the cassette or FOUP with the substrate **100**. As described above, oxygen tends to react with the copper layer **110** formed over the substrate **100** to form the copper oxide layer **140**.

In order to address this problem, a "Q-time" is required after a critical process step is performed in the semiconductor manufacturing process. The next substrate process must be performed within a set predetermined time period or Q-time, such as from 2 to 4 hours. If a subsequent process, such as formation of a barrier layer, does not occurred within the time period, a cleaning process is required to remove any copper oxide layer **140** formed over the copper layer **110**.

Due to high integration of semiconductor devices over substrate **100**, a semiconductor process usually has a plurality of the critical steps each with an associated Q-time designed to protect the substrate. These Q-time requirements complicate the manufacturing processes. In addition, if a Q-time is missed, additional steps such as cleaning steps increase process time and complexity.

By way of background, U.S. Pat. No. 6,506,009 provides a description of a prior art cassette stocker, the entirety of which is hereby incorporated by reference herein. U.S. Patent Publication No. 2003/0070960 provides a description of a prior art wafer cassette for storing and transporting wafers, the entirety of which is hereby incorporated by reference herein. Neither of these references provide a means for limiting formation of oxidation on or otherwise protecting surfaces of substrates when substrates are stored within or transferred to cassettes or FOUPs.

From the foregoing, improved cassettes or carriers and facility interfaces therefor are desired.

SUMMARY OF THE INVENTION

In accordance with some exemplary embodiments, a carrier comprises an enclosure, a cabinet and at least one substrate holder. The enclosure comprises a door. The cabinet is coupled to the carrier. The cabinet comprises at least one valve and contains at least one reduction fluid. The substrate holder is disposed within the enclosure to support at least one substrate.

The above and other features of the present invention will be better understood from the following detailed description of the preferred embodiments of the invention that is provided in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Following are brief descriptions of exemplary drawings. They are mere exemplary embodiments and the scope of the present invention should not be limited thereto.

FIG. **1** is a schematic drawing showing a prior art via hole structure.

FIG. **2**A is a schematic side cross-sectional view of an exemplary wafer carrier.

FIG. **2**B is a schematic end view of the carrier of FIG. **2**A shown with the door of the carrier removed.

FIG. **3**A is a schematic illustration of an exemplary facility interface.

FIG. **3**B is an enlarged drawing of the stage, carrier, sealing apparatus and wall of the enclosure shown in FIG. **3**A.

FIGS. **4**A-**4**C are schematic cross-sectional views illustrating an exemplary process of attaching the carrier **200** to the facility interface **300** as shown in FIG. **3**B.

FIGS. **5**A-**5**B are schematic drawings showing exemplary pressure changes within an enclosure after loading and unloading of the enclosure on a stage.

DESCRIPTION OF THE PREFERRED EMBODIMENT

This description of the exemplary embodiments is intended to be read in connection with the accompanying drawings, which are to be considered part of the entire written description. In the description, relative terms such as "lower," "upper," "horizontal," "vertical," "above," "below," "up," "down," "top" and "bottom" as well as derivatives thereof (e.g., "horizontally," "downwardly," "upwardly," etc.) should be construed to refer to the orientation as then described or as shown in the drawing under discussion. These relative terms are for convenience of description and do not require that the apparatus be constructed or operated in a particular orientation.

FIG. 2A is a schematic cross-sectional view of an exemplary wafer carrier. The carrier **200** comprises an enclosure **210** comprising a door **220** for opening and closing the enclosure **210**. A hollow cabinet **230** is coupled to the carrier or formed integrally therein. The cabinet **230** can be, for example, a square, rectangular, oval or other shape that is adapted to store a fluid. FIG. **2**A shows the cabinet **230** located proximate to a wall **260**, such as the top wall, of the enclosure **210**. In other embodiments, the cabinet **230** is located away from the door **220** so that the positioning of the cabinet **230** will not interfere transfer of substrates **280**. The cabinet **230** can vertically or horizontally disposed on a sidewall, top wall or bottom wall of the carrier **230**. In still other embodiments, the cabinet **230** can be disposed on the door **220**. The cabinet **230**, which is essentially a tank, contains at least one fluid **235** therein, shown partially filling cabinet **235**. The cabinet **230** includes at least one valve, such as a valve **240** and an injection valve **250**. At least one substrate holder **270** is disposed within the enclosure **210** and coupled to at least one of the walls **260** of the enclosure **210** to carry at least one wafer substrate, display substrate, such as liquid crystal display (LCD), plasma display, cathode ray tube display or electro luminescence (EL) lamp, light emitting diode (LED) substrate or reticle (collectively referred to as, substrate **280**), for example.

The carrier **200** can be, for example, a cassette, front opening unified pod (FOUP), reticle carrier or other carrier known in the art for carrying one or more semiconductor substrate. In an embodiment, the carrier **200** is a FOUP and the door **220** is located on a side of the carrier **200**. In this embodiment, the carrier **200** also includes a frame **225** so that the door **220** can be moved into and from the frame **225**. Further, a surface **225***a* of the frame **225** is attached to a sealing apparatus disposed on a facility interface (not shown in FIG. **2**A, but shown in FIG. **4**B). In some embodiments, the carrier **200** is a cassette and the door **220** is located at the bottom of the carrier. In still other embodiments, the door **220** is located at the top of the carrier **200**. The dimensions of the door **220** do not necessarily match the dimensions of a face of the enclosure **210** at which it is located as shown in FIG. **2**A. For example, the enclosure **210** can comprise a sidewall **260** having an opening through which a substrate **280** can be placed. In this embodiment, the door **220** need only cover the opening. In some embodiments, the door **220** is configured within or coupled to the sidewall **260** so that it can move (e.g., slide or swing) to close and open the opening in the sidewall **260** of the enclosure **210**. Alternatively, the door **220** can be removed. From the foregoing, it should be understood that the enclosure **210** need only include an opening having dimensions that allow the substrates **280** to be moved smoothly in and out of the enclosure **210** and a door **220** (i.e., cover) for covering the opening to seal the enclosure **210**.

In the embodiment of FIG. **2**A, the enclosure **210** is sealed when the door **220** is connected to or closed over the opening to the enclosure **210**. In some embodiments, a sealing apparatus **215** is disposed between the enclosure **210** and the door **220** to seal the carrier **200** against a surface. The sealing apparatus **215** can be disposed on the enclosure **210**, door **220** or both. The sealing apparatus **215** can be, for example, a rubber strip, O-ring, gel or other apparatus adapted to seal the carrier **200**. In other embodiments, the sealing apparatus **215** is not required if the enclosure **210** and the door **220** are tightly connected, such as by fasteners.

The door **220** is removed or opened to transfer at least one substrate **280** into or from the enclosure **210**. The enclosure **210** is connected to an interface apparatus (not shown) during the substrate transfer. The sealing apparatus **215** (on the enclosure **210** and/or interface apparatus) seals the gap between the enclosure **210** and the interface apparatus as described in more detail below. In some embodiments, it is possible that the substrate **280** is exposed to the environment when the door **220** is removed. The enclosure **210**, however, is either immediately contacted with the interface apparatus or sealed by the door **220** after the transfer of the substrate **280**. The duration of the substrate **280** exposure to the environment is short enough that little reaction can occur between the substrate **280** and the environment. In addition, in embodiments, a reduction gas is provided within the carrier **200** to reduce the oxidation as described below.

Referring to FIG. **2**A, the pressure within the sealed carrier **200** is maintained higher than the pressure of the environment surrounding the carrier **200** in order to prevent or reduce gas flowing from environment into the carrier **200** during prolonged storage periods. For example, if the environmental pressure is about 1 atm, the pressure within the carrier **200** is maintained higher than 1 atm. Accordingly, the required pressure within the carrier **200** can vary with the environmental pressure. In some embodiments, the pressure within the carrier **200** is maintained within a selected range, such as from about 1.0 atm to about 2.5 atm. In some preferred embodiments, the pressure within the carrier **200** is maintained within a selected range, such as from 1.0 atm to about 1.3 atm, so that the pressure difference between the environment and the carrier **200** will not crash the carrier **200**.

The desired pressure is maintained by a gas provided in the carrier **200**. The gas can comprise a reduction gas, a gas that is non-reactive with the substrate **280** or a mixture thereof. A reduction gas can be provided to reduce or prevent oxide formation on the surfaces of the substrate **280** due to exposure of the substrate **280** during transfer of the substrate **280** into the carrier **200** or due to air trapped in the carrier **200**. In some embodiments, the substrate **280** comprises exposed copper layers (not shown in FIG. **2**A, but shown in FIG. **1**) and the reduction gas comprises hydrogen (H_2), ammonia (NH_3), or other reduction gas or mixture thereof. The non-reactive gas component can comprise an inert gas such as helium (He), neon (Ne), argon (Ar), krypton (Kr), xenon (Xe), radon (Rn) or other gas such as nitrogen (N_2) that does not substantially react with the surfaces of the substrates **280** to form an oxide or other undesirable reaction (e.g., absorption of water within a low-k dielectric layer). In some embodiments, the non-reactive gas can be provided into the carrier **200** by a valve coupled to the carrier **200** and to an external source. In still other embodiments, the non-reactive gas may be provided into the carrier **200** from the cabinet **230** if the cabinet **230** comprises a mixture of the reduction fluid and non-reactive fluid or from a second cabinet (not shown).

The amount of the reduction gas should be controlled to prevent explosion or other volatility if the selected reduction gas is volatile. For example, if H_2 is the reduction chemical within the carrier **200**, the amount of H_2 within the carrier **200** should be equal to, or less than, about 4% per volume. One preferred amount of H_2 is between about 10 parts per million (ppm) to about 4% per volume with the remaining percentage composed of at least one non-reactive gas. In some embodiments, if NH_3 is the reduction chemical within the carrier **200**, the amount of NH_3 within the carrier **200** is equal to, or less than, about 15.5% per volume. One preferred amount of NH_3 is between about 10 parts per million (ppm) to about 15.5% per volume with the remaining percentage composed of at least one non-reactive gas.

In some embodiments, the sealing apparatus **215** does not completely seal the carrier **200** and the gas within the carrier **200** is allowed to leak or flow into the environment surrounding the carrier **200**, at least in small amounts. If the gas is hazardous, such as NH_3, the gas within the carrier **200** is controlled so that the leakage of the gas does not result in levels harmful to human beings. For example, with NH_3 the levels should not be allowed to rise to 25 ppm in the environment. The amount of the gas, e.g., NH_3, within the carrier **200** may also be adjusted to eliminate this concern.

Referring to FIG. **2**A, the cabinet **230** comprises at least one reduction fluid and/or non-reactive fluid **235** therein stored as a gas, liquid or both (collectively, "fluid"). The valve **240**, which comprises a needle valve in an embodiment, releases a gas formed by the fluid **235** within the cabinet **230** into the carrier **200** when the pressure within the carrier **200** is at or lower level than a predetermined or measured pressure, for example, the environmental pressure (e.g., 1 atm). The injection valve **250** allows for filling the fluid **235** into the cabinet **230** when the amount of the fluid **235** within the cabinet **230** is lower than a predetermined or desired amount. In some embodiments, the fluid comprises a mixture of N_2 and H_2 in which H_2 is from of about 4% per volume to of about 10% per volume. In other embodiments, the fluid **235** is liquid H_2. Under the pressure within a range from about 1 atm to about 2.5 atm and at room temperature, H_2 is in a gas phase. Once liquid H_2 is released into this environment, it converts to the gas phase and fills into the enclosure **210** of the carrier **200**. In embodiments, the gas of the fluid **235** can be filled into the enclosure **210** by an installed pump (not shown). In some embodiments, a pressure gauge **261** is coupled to the valve **240** by connection **265** to send a signal to trigger the valve **240** to release the reduction fluid gas. In other embodiments, the pressure gauge **261** is not required if the valve **240** is time set to release the gas of the fluid **235** or is itself pressure sensitive.

In some embodiments, a gauge (not shown) is coupled to, or installed in, the injection valve **250**. This gauge senses the amount of the fluid **235** within the cabinet **230** and sends a signal to trigger the injection valve **250** to fill the fluid **235** into the cabinet **230** from a source such as an external fluid tank (not shown) if the amount of the fluid **235** within the cabinet **230** is less than a predetermined amount. Alternatively, the gauge is not required if, for example, the injection valve **250** is time set to fill the fluid **235** into the cabinet **230** or itself serves as a gauge.

In some embodiments, only one of the valves **240** and **250** is used if the selected valve is configured to allow both the injection of the reduction fluid **235** into the cabinet and the release of the gas of the reduction fluid **235** into the enclosure **210** under the conditions described above.

In some embodiments, the cabinet **230** is not required if fluid **235** is filled directly into the enclosure **210** from an external source through a valve.

If a pump is not provided, in order to speed delivery of the gas into enclosure **210**, the cabinet **230** is disposed at a top region of the enclosure **210** when the molecular weight of the fluid **235** is larger than the molecular weight of the gas within the carrier **200**. For example, assume that the fluid **235** is NH_3 and the gas within the carrier **200** is a mixture of NH_3 and He. The molecular weight of NH_3 is 17 and the molecular weight of He is 2. If the gas comprises 10% NH_3 and 90% He, the molecular weight of the gas is about 3.5, which is less than 17. Thus, the cabinet **230** is disposed at the top region of the enclosure **210** so that NH_3 efficiently diffuses into the enclosure **210** when the valve **240** is actuated. In contrast, the cabinet **230** is disposed at a bottom region of the enclosure **210** if the molecular weight of the fluid **235** is less than the molecular weight of the gas within the carrier **200**. For example, assume that the fluid **235** comprises H_2 and the gas within the carrier **200** comprises a mixture of H_2 and nitrogen. The molecular weight of H_2 is 2 and the molecular weight of nitrogen is 28. If the gas comprises 1% H_2 and 99% nitrogen, the molecular weight of the gas is about 27.74, which is larger than 2. Therefore, the gas of the fluid **235** within the cabinet **230** disposed at the bottom region of the enclosure **210** efficiently diffuses into the enclosure **210** when the valve **240** is actuated. Note that the "top region" is not limited to the top wall **260** as shown in FIG. **2**A. The top region can be the top portion of the sidewall **260** of the enclosure **210**. Also, the bottom region can be the bottom portion of the sidewall **260** of the enclosure **210**.

The configuration of the cabinet **230** is not strictly required as described above. The gas released from the fluid **235** can uniformly diffuse within the enclosure **210** if there is sufficient time for the gas to diffuse. If the gas diffuses within the enclosure **210** in a manner that effectively prevents oxidation or other chemical reactions with the substrate **280**, the cabinet **230** can be disposed at any desired location.

In some embodiments, transfer of the substrate **280** is performed within an environment such that air will not flow into the enclosure **210** when the door **220** is removed. In this embodiment, the fluid **235** can be, for example, a fluid of a non-reactive gas to the substrate **280** (e.g., an inert gas or nitrogen) without need for the reduction fluid.

Again referring to FIG. **2**A, in one embodiment, the pressure gauge **261** and the release valve **263** are disposed on the sidewall **260** of the enclosure **210**. The pressure gauge **261** is adapted to sense the pressure within the carrier **200**. The release valve **263** is adapted to adjust the pressure within the carrier **200** when the pressure within the carrier **200** is higher than a desired pressure limit, such as about 2.5 atm. Adjusting the pressure within the carrier **200** can prevent potential explosions resulting from a volatile reduction gas within the carrier **200** as described above. In some embodiments, the pressure gauge **261** senses the pressures within and outside the carrier **200**. If the pressure within the carrier **200** is higher than the pressure outside the carrier **200** by a certain amount, the pressure gauge **261** sends a signal to the valve **263** to trigger release of at least some of gas within the carrier **200**.

In some embodiments, the release valve **263** comprises a spring (not shown) which has a mechanical property such that the pressure within the carrier **200** presses the spring to open the release valve **263**. For those embodiments, the pressure gauge **261** is not required as the release valve **263** is pressure sensitive and configured as needed. In other embodiments, the release valve **263** comprises a piezoelectric material which has a material property such that the pressure within the carrier **200** presses the piezoelectric material to generate a signal to turn on the release valve **263**. For this embodiment, the pressure gauge **261** is also not required though it can still be coupled to the valve **240**.

Referring to FIG. **2**A, the walls **260** of the enclosure **210** comprise one or more than one substrate holders **270**. The substrate holders **270** are provided to support the substrates **280**. The substrate holders **270** can be, for example, plates, small extrusions on or grooves within the walls **260** or other holding structures capable of holding the substrate **280**.

FIG. **2**B is a schematic end view of an exemplary carrier **200** shown with the door **220** of the carrier **200** removed. In FIG. **2**B like items are indicated by like reference numbers as in FIG. **2**A. In this view, the sealing apparatus **215** can be seen disposed around the opening of the enclosure **210**.

FIG. **3**A is a schematic cross-sectional view of an exemplary facility interface system. The facility interface system comprises an enclosure **300**. The enclosure **300** comprises a sealed space **310** having a gas therein and at least one door **325** on or in at least one of the walls **320** of the enclosure **300**.

The gas comprises a gas as described above in connection with the description of carrier **200**, e.g., a reduction gas, non-reactive gas or mixture thereof. At least one robot **330** is disposed within the enclosure **300**. At least one stage **340** is disposed outside of the sealed space **310** and on or proximate to an outer surface of one of the walls **320** of the enclosure **300** proximate to the door **325** for supporting the enclosure **210**. Optionally, the enclosure **210** can be directly coupled to and be supported by the wall **320** of the enclosure **300**. The door **325** is provided so that the substrates **280** stored in the enclosure **210** can be properly transferred between the enclosure **210** and the facility interface. At least one valve is provided for the enclosure **300**. In some embodiments, the enclosure **300** includes a valve **350** and a release valve **360**. A pressure gauge **370** may be coupled to the valves **350** and **360**. The robot **350** operates to transfer the substrate **280** between the carrier **200** and the process chamber **380** through the doors **323** and **325**.

The pressure within the enclosure **300** is maintained higher than the pressure of the environment surrounding the enclosure **300** through cooperation of the valves **350** and **360** and gauge **370** in order to prevent or reduce gas flow from the environment into the enclosure **300**. For example, if the environmental pressure is about 1 atm, the pressure within the enclosure **300** is maintained higher than about 1 atm. Accordingly, the pressure within the enclosure **300** can vary with the environmental pressure. In some embodiments, the pressure within the enclosure **300** is from about 1.0 atm to about 2.5 atm. The enclosure **300** includes a gas therein including at least one of a reduction gas and a non-reactive gas with respect to the substrate **280** as described above in connection with the enclosure **210**. The reduction gas is provided to reduce or prevent oxidation on the surfaces of the substrates **280** and its levels are controlled as described above in connection with the carrier **200**.

In some embodiments, the enclosure **300** is connected to a process or transfer chamber **380**. A process chamber **380** can be, for example, a wet chemical plating bench, a dry etch chamber for via opening, a chamber for formation of a copper seed layer, a chamber for copper chemical mechanical polish (CMP), a chamber for formation of low-k dielectric material or other chamber which forms or exposes material on the substrate that may react if exposed to the environment.

Referring to FIG. 3A, the valve **350** and the exhaustion valve **360** are disposed on one of the walls **360** of the enclosure **300**. The valve **350** injects the mixture gas including the reduction gas into the enclosure **300** from a source (not shown) to adjust the pressure therein when a pressure within the enclosure **300** is lower than a predetermined pressure, such as about 1 atm. In some embodiments, the gas introduced by the valve **350** comprises a mixture of N_2 and H_2 in which H_2 is from of about 4% per volume to of about 10% per volume. The exhaustion valve **360** exhausts the gas from the enclosure **300** to adjust the pressure therein when the pressure within the enclosure **300** is higher than another predetermined pressure, such as about 2.5 atm. Rather than utilizing both valves **350** and **360**, in some embodiments, only one valve **350** or **360** is used. In such embodiments, the valve **350** or **360** injects the mixture gas comprising the reduction gas into the enclosure **300** when the pressure within the enclosure **300** is lower than a predetermined pressure, such as 1 about atm, and exhausts the mixture gas comprising the reduction gas from the enclosure **300** when the pressure within the enclosure **300** is higher than another predetermined pressure, such as about 2.5 atm. In some embodiments, the valve **350** and/or the exhaustion valve **360** is coupled to a mass flow controller (MFS) (not shown) to control the flow of the gas into and out from the enclosure **310**, respectively.

In some embodiments, a pressure gauge **370** is coupled to the valve **350**, exhaustion valve **360** or both so that the pressure gauge **370** sends a signal to trigger the valve **350** to inject the mixture gas including the reduction gas into the enclosure **300** and the exhaustion valve **360** to exhaust the mixture gas including the reduction gas from the enclosure **300** when the measured pressure reaches predetermined limits. In other embodiments, the pressure gauge **370** is not required if the valve **350** and the exhaustion valve **360** are time set to inject and exhaust the mixture gas comprising the reduction gas, respectively, or the valves are pressure sensitive or include integral gauges.

In some embodiments, the pressure gauge **370** senses the pressures within and outside the enclosure **300**. If the pressure within the enclosure **300** is higher than the pressure outside the enclosure **300** by a predetermined amount, the pressure gauge **370** sends a signal to trigger the exhaustion valve **360** to release the gas within the enclosure **300** until the desired pressure differential is reached.

In some embodiments, only the reduction gas, rather than the mixture gas, is injected into the enclosure **300** by the valve **350**. However, the pressure and volume percentage of the mixture gas within the enclosure should be maintained in such a way as described above. If the conditions of the mixture gas within the enclosure **300** can be substantially maintained as described above, the injection of the reduction gas is acceptable. Factors for consideration in locating the valves **350** and **360** are described above in connection with the carrier **200** and can be applied to the enclosure **300**.

FIG. **3**B is an enlarged, partial view of the stage **340**, enclosure **210**, sealing apparatus **215** and wall **320** of the enclosure **300** shown in FIG. **3**A. After the door **220** of the carrier **200** is removed, the door **325** on the wall **320** is opened so that the substrates **280** can be transferred between the enclosure **210** and the facility interface by the robot **330**. The enclosure **210** is connected to the wall **320**. The sealing apparatus **215** seals the enclosure **210** against the wall **320** of the enclosure **300**. In some embodiments, the pressure and gas conditions within the enclosure **300** are substantially similar to those within the carrier **200**. In other embodiments, they can be different as long as such difference does not cause a chemical reaction on the surface of the substrate **280**.

Again referring to FIG. **3**A, after the substrate **280** is removed from the enclosure **210** into the enclosure **300**, the door **323** between the process chamber **380** and the enclosure **300** is opened. The substrate **280** is then transferred into the process chamber **380** for processing, and the door **323** between the process chamber **380** and the enclosure **300** is closed. After the processing, the substrate **280** is transferred from the process chamber **380** into the enclosure **300**. The condition within the process chamber **380** may be different from that within the enclosure **300**, and the opening of the door **323** between the process chamber **380** and the enclosure **300** may destroy the desired condition within the enclosure **300**. However, the valve **350** and the release valve **360** are able to promptly recover the condition within the enclosure **300** back to a desired condition as described above after closing of the door **323** between the process chamber **380** and the enclosure **300**. The time to recover such condition may be in the order of tens of seconds, which is short enough such that, for example, any oxidation occurring on the surface of the substrate **280** is negligible, i.e., will not adversely affect the connection between the surface of the copper layer **110** and a conductive via plug filled within the via hole **130** as shown in FIG. **1**.

FIGS. **4A-4C** are schematic cross-sectional views illustrating an exemplary process of attaching the carrier **200** to the facility interface **300** as shown in FIG. **3B**.

Referring to FIG. **4A**, the carrier **200** is moved approached to a wall **310***a* of the enclosure **310**. The wall **310***a* of the enclosure **310** includes the door **325**, which is configured to cover an opening into the enclosure **310**. A sealing apparatus **328**, such as a rubber strip, O-ring, gel or other apparatus adapted to seal the enclosure **310**, is disposed on the inner surface of the wall **310***a* and between the wall **310***a* and the door **325** so that the door **325** can be attached to the wall **310***a* to tightly seal the enclosure **310**. In some embodiments, the sealing apparatus **328** is disposed on the door **325** at the periphery area surrounding the opening **325***a* (shown in FIG. **4C**). The outer surface of the wall **310***a* includes another sealing apparatus **327**, such as a rubber strip, O-ring, gel or other apparatus adapted to seal the region between the doors **220** and **325** after the attachment of the carrier **200** and the wall **310***a*. The sealing apparatus **327** is adapted to seal the gap between the frame **225** of the carrier **200** to the wall **310***a*, when the door **220** is attached to the wall **310***a* as shown in FIG. **4B**. In some embodiments, the sealing apparatus is disposed on the surface **225***a* of the frame **225** surrounding the opening **325***a* (show in FIG. **4C**).

At least one fasteners **322**, such as clamps, knob clamps, clips or other devices that can fasten the carrier **200** to the wall **310***a*, are configured on the outer surface of the wall **310***a* proximate to edges of the sealing apparatus **327** to fasten the carrier **200**, such as the frame **225**. The fasteners **322** can be, for example, rotated or vertically moved to fasten the carrier **200**. The number of the fasteners **322** is not limited to the number shown in FIG. **4A**. It can be one or more than one fasteners **322** as long as the carrier **200** can be fastened to the wall **310***a*.

At least one valves, such as a valve **324** and a valve **326**, configured within the wall **310***a*. The opening of the valves **324** and **326** are configured within an area enclosed by the sealing apparatus **327** to remove air from a region sealed by the sealing apparatus **327** as shown in FIG. **4B** and inject an inert gas or a mixture including the reduction gas as set forth above into the region, respectively. In some embodiments, only one of the valves **324** and **326** is used if the selected valve is configured to allow both the removal of the air from the region sealed by the sealing apparatus **327** and the injection of an inert gas or a mixture gas including the reduction gas into the region. In some embodiments, the valves **324** and/or **326** are coupled to at least one mass flow controllers (MFC) to control the removal rate of air and the injection rate of the inert gas or the mixture gas.

Referring to FIG. **4B**, the carrier **200** is attached to the wall **310***a*, such as the sealing apparatus **327**. Under this embodiment, the surface **225***a* of the frame **225** is attached against the sealing apparatus **327** so that the sealing apparatus tightly seals the gap between the doors **215** and **325**. The valve **324** then removes air trapped within the region sealed by the sealing apparatus **327**. The valve **326** then injects the inert gas or the mixture gas within this region so that this region is filled with the gas so that does not substantially react with the substrates **280** stored in the carrier **200**. In some embodiments, the cycle of the removal of the air and the injection of the inert gas or mixture gas is performed at least one times, such as about 3-5 times, so that the air trapped within this region sealed by the sealing apparatus **327** is substantially removed.

Referring to FIG. **4C**, the doors **325** and **220** are sequentially removed to locations that will not interfere the transfer of the substrates **280**. The locations can be, for example, proximate to the inner surface of the wall **310***a* and below the opening **325***a* that is covered by the door **325**. In addition, the dimension of the door **220** is smaller than that of the door **325**. The door **220** thus can be removed towards the enclosure **310** after the removal of the door **325**. As described above, the enclosure **310** and the carrier **200** contain the gas including the reduction gas. Further, the air trapped within the region sealed by the sealing apparatus **327** and the inert gas or mixture gas is then injected into this region. Accordingly, the substrates **280** can be transferred between the enclosure **310** and the carrier **200** without substantial exposure to air. The present invention, however, is not limited thereto. The transfer of the substrates **280** can still be performed as set forth in connection with FIG. **3A**, for example.

FIGS. **5A-5B** are plots showing a pressure change within the enclosure **210** during an unloading/transfer/reloading cycle of the carrier **200** from the stage **340**.

Referring to FIG. **5A**, Pe represents the pressure of the environment surrounding the enclosure **210**, P**0** represents a low-level pressure, P**1** represents the selected pressure within the enclosure **300** of the facility interface, P**2** represents the minimum desired pressure within the enclosure **200** and P**3** represents the maximum desired pressure within the enclosure **210**. In some embodiments, if either the pressure of the enclosure **310** or the carrier **200** is lower than P**0**, it is assumed that leakage of the gas occurs between the environment and the enclosure **310** and/or the carrier **200**. The enclosure **310** and/or the carrier **200** thus can be checked before the use of transferring and carrying the substrates **280**.

Prior to T**1**, the enclosure **210** is seated on the stage **340** and physically coupled to the enclosure **300** with the door **220** opened or removed and with the door **325** opened as shown in FIG. **3B**. Because the spaces within the enclosures **210** and **300** are connected, the pressure within the enclosure **210** is substantially equal to the pressure within the enclosure **300**, e.g., P**1**. After one or more substrates **280** are transferred to the carrier **200**, at the time T**1**, the door **220** is attached to or closed over the carrier **200** to seal the enclosure **210** as shown in FIG. **2A**. The carrier **200** is lifted from the stage **340** and transported to a selected processing apparatus during time between times T**1** to time T**2**. In this embodiment, the desired minimum pressure P**2** within the enclosure **210** is higher than the environment pressure Pe and the pressure P**1** maintained within the enclosure **300**. In order to increase the pressure within the enclosure **210** to the desired minimum pressure P**2**, the valve **240** shown in FIG. **2A** operates to release the gas of the fluid **235** stored within the cabinet **230** into the enclosure **210** to increase the pressure. At the time T**2**, in order to perform a subsequent process, the enclosure **210** is reloaded, i.e., seated, on a stage **340** of a facility interface associated with a second process apparatus and the door **220** is removed. The enclosure **210** is physically coupled to an enclosure **300** as shown in FIG. **3B**. FIG. **5A** shows that the time between T**1** and T**2** was not long enough to allow the pressure within the enclosure **210** to reach the desired minimum pressure P**2**. At time T**2**, because the spaces within the enclosures **210** and **300** are connected and the space within the enclosure **300** is substantially larger than that within the enclosure **210**, the pressure within the enclosure **210** is pulled down and maintained substantially equal to the pressure P**1** within the enclosure **300**.

The timeline of FIG. **5B** shows the operation of the carrier **200** when sufficient time passes from a time T**1** (where the carrier **200** is unloaded from a facility interface) for the pressure within the carrier **200** to reach the desired minimum pressure P**2**. From time T**1** to time T**4**, substrates **280** are stored and/or transported within the carrier **200**. At time T**3**, the pressure reaches the desired minimum pressure P**2**, and from time T**3** to T**4** the pressure is maintained within the desired pressure range (P**2** to P**3**) by operation of valves **240**, **250**, **263**, pressure gauge **261** and/or cabinet **230**. At time T**4**, the carrier **200** is again loaded onto a stage of a facility interface. The door **220** of the carrier **200** is opened or removed and the carrier **200** is coupled to an enclosure **300**, at which time the pressure equalizes with the pressure P**1** of the enclosure **300**.

In still other embodiments, after the door **220** is closed, the valve **240** injects the reduction gas into the carrier **200**. The release valve **263**, such as a spring, releases the gas within the carrier **200** to the environment if the pressure within the carrier **200** is higher than P**2** without the use of the pressure gauge **261**.

Although FIGS. **5**A-**5**B illustrate the operation of embodiments where P**1** is less than P**2**, in some embodiments, the desired pressure to be maintained within the enclosure **210** is substantially equal to the pressure within the enclosure **310**. In still other embodiments, the desired pressure to be maintained within the enclosure **210** is lower than the pressure within the enclosure **310** but above the environment pressure Pe.

Although the present invention has been described in terms of exemplary embodiments, it is not limited thereto. Rather, the appended claims should be constructed broadly to include other variants and embodiments of the invention which may be made by those skilled in the field of this art without departing from the scope and range of equivalents of the invention.

What is claimed is:

1. A carrier, comprising:

an enclosure comprising a plurality of walls and a door;

a cabinet coupled to the carrier within the enclosure, the cabinet comprising a valve and containing a fluid; wherein the valve is operable to introduce said fluid into said enclosure, and the fluid is selected from the group consisting of a reduction fluid and a non-reactive fluid; and

a substrate holder disposed within the enclosure to support a substrate.

2. The carrier of claim **1**, wherein the pressure within the carrier is maintained at a pressure higher than the pressure of the environment surrounding the carrier.

3. The carrier of claim **2**, further comprising means for maintaining the pressure within the carrier within a selected pressure range.

4. The carrier of claim **3**, wherein the selected pressure range is from about 1.0 atm to about 2.5 atm.

5. The carrier of claim **1**, further comprising a sealing apparatus disposed between the enclosure and the door to seal the carrier when the door is in a closed position, and to seal the enclosure and an interface apparatus when the door is in an open position or removed.

6. The carrier of claim **1**, wherein the cabinet comprises a first valve and a second valve, the second valve positioned to allow release of a gas of the fluid into the enclosure when a pressure within the enclosure is lower than a predetermined pressure level, and the first valve is positioned to allow filling of the fluid into the cabinet.

7. The carrier of claim **6**, wherein the predetermined pressure level is about 1 atm.

8. The carrier of claim **1**, wherein the reduction fluid comprises a mixture of hydrogen (H_2) and ammonia (NH_3), and the mixture is in gas or liquid form.

9. The carrier of claim **8**, wherein the cabinet is disposed proximate to a bottom region of the enclosure and a molecular weight of the reduction fluid is less than a molecular weight of a gas within the carrier, or the cabinet is disposed at a top region of the enclosure and the molecular weight of the reduction fluid is more than the molecular weight of the gas within the carrier.

10. The carrier of claim **1** further comprising a gas within the enclosure, wherein the gas comprises a reduction gas or a non-reactive gas with respect to a surface of the substrate.

11. The carrier of claim **10**, wherein the reduction gas comprises at least one of hydrogen and ammonia, and the non-reactive gas comprises at least one of an inert gas and nitrogen.

12. The carrier of claim **11**, wherein hydrogen is equal to or less than about 4% per volume and ammonia is equal to or less than about 15.5% per volume.

13. The carrier of claim **1** further comprising a release valve within the enclosure, the release valve being actuated to adjust a pressure within the carrier if the pressure is higher than a predetermined pressure level.

14. The carrier of claim **13**, wherein the predetermined pressure level is about 2.5 atm.

15. The carrier of claim **13** further comprising a pressure gauge coupled to the release valve.

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